Remarks

Applicant submits this amendment in response to the final office action mailed July 1, 2005. The prior claims 1-17, 24 and 26-28 were rejected as anticipated by or obvious over a combination of one or more of:

Watanabe JP2-117088

Watanabe JP2-117089

Terry GB 752,268

Pilavidzic US 2003/0121908 A1

Nishi U.S. 5,294,769

More specifically, prior claims 1, 3, 4 and 7 were rejected under 102(b) as anticipated by either of Watanabe '088 or Watanabe '089.

Claims 1, 3, 4 and 7 were rejected under Section 102(b) as anticipated by Terry.

Claims 1-17, 24 and 26-28 were rejected under Section 103(a) as obvious over Pilavidzic or Nishi, in view of Terry or Watanabe '089.

Applicant's prior argument was considered moot in view of the new grounds of rejection. Further, Applicant's prior argument was found not persuasive on the grounds "the claims are so broadly worded that claim 1 reads on any power source generating current pulses with harmonics contents" and that "the use of harmonics for efficient heating in an induction heating device is shown to be notoriously old and well known by Terry and Watanabe."

In addition, a provisional obvious-type double patenting rejection was made over copending application 10/884,851.

The Amended Claims

New independent apparatus claim 29 recites a heating apparatus including a heater coil for inductive heating and a power source for supplying to the heater coil current pulses which are non-sinusoidal and have steeply varying portions providing high frequency harmonics in the heater coil. Support for these features may be found in the original claims and in the specification at paragraphs 13, 42, 44, 62, 76, 83, 119 and elsewhere. The method and dependent apparatus claims are similarly based upon the original claims and specification.

Thus, the pending claims are fully supported by the original application.

The specification describes how to produce pulses of the kind claimed and these pulses have the technical effect of increasing the inductive heating efficiency. The term "high frequency harmonics" is clarified in the description (see, for example, paragraph 133 of the application) as meaning harmonics at frequencies above the fundamental or root frequency. As such, a skilled person could readily determine whether current pulses fall within the scope of the proposed claims by performing a Fourier transform of the pulses. The claimed current pulses are "non-sinusoidal" and "have steeply varying portions providing high frequency harmonics." A skilled person would understand that these terms are intended to discount smoothly varying signals such as slightly distorted (damped) sinusoidal signals which have a very small harmonic content. The terms are further clarified by the context in which they are used as the claim specifies that the steeply varying portions provide high frequency harmonics. It is clear that the term "steeply" should be interpreted such that the portion/edge should be steep enough to

provide a significant amount of high frequency harmonics in the pulse. Again, this can readily be determined by performing a Fourier transform of the pulses as described at, for example, paragraph 102 of the application. As such, a skilled person could readily determine whether current pulses fall within the scope of the proposed claims.

The present invention is directed to a heating apparatus and method that utilizes a particular pulse signal with high frequency harmomics, i.e. non-sinusoidal current pulses having steeply varying portions providing high frequency harmomics. The high frequency harmonics can be used to increase the power inductively delivered to the load (article being heated), based on the combination of the fundamental (root) and harmonic frequency components of the signal and their amplitudes. Applicant has experimentally determined that the equivalent eddy current resistance R_e of the load is augmented with the use of such current pulses when compared to sinusoidal currents (where for sinusoidal currents R_e increases with the square root of the frequency). The present invention thus allows, for example, one to increase the power of inductive heating without requiring a corresponding increase of current in the heater coil and/or without an increase in the switching frequency.

The claims of the present application are directed to an apparatus and method wherein a power source supplies non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics to the heater coil. As described in the various embodiments in the specification, the signal comprises narrow current <u>pulses</u>, which include sharp slopes (see 44 in Figs. 4-6 and in Fig. 9) and which are separated by relatively long delays between pulses (see paragraphs 76 and 100). In one experiment, comparing the performance of a heating system powered by a 60 Hz

sinusoidal signal voltage and a current pulse signal according to one embodiment of the present invention, the current pulse signal increased the eddy current resistance much more than the expected increase due to the increase in fundamental (root) frequency (paragraphs 101-111). A Fourier transform of such current pulses can be used to illustrate the high level of energy in the high frequency harmonics (see paragraphs 102-109).

The use of the claimed current pulses represents a significantly different approach to inductive heating than currently utilized, as described below.

Traditional inductive heating systems utilize a resonant frequency power supply which delivers a sinusoidal current of resonant frequency to the heater coil. In such systems, in order to increase the heating power delivered to the load, a large current must be delivered to the load. There are numerous problems generated by the use of such large currents, including large power losses in the switching circuit, parasitic heating of the coil, the necessity for large tank capacitors (for tuning the resonant circuit) and the complexity of the switching circuit. Most notably, such systems deliver to the load a sinusoidal resonant frequency current which signal is a continuous function of time (not a pulsed signal).

Prior Art Cited in the Office Communication

Terry (GB 752,268) appears to suggest the use of harmonics for inductive heating. However, Terry differs from the presently claimed invention in providing harmonics in a continuous signal. In this regard, Terry does not teach current pulses. Also, Terry's distorted sinusoidal signal contains some third, little fifth and minimal

seventh harmonics. As such, the signal disclosed by Terry does not have steeply varying portions and inevitably the total energy content of the third, fifth and seventh harmonics of Terry's distorted sinusoidal signal is relatively small.

Thus, Terry does not teach or suggest Applicant's claimed non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics. Rather, Terry proposes a distorted but substantially continuous sinusoidal signal. Furthermore, Terry's signal will inevitably include only a small portion of the energy in harmonics. In contrast the non-sinusoidal current pulses having steeply varying portions in accordance with the present invention will inevitably achieve a substantial amount of pulse energy in the high frequency harmonics. This is not disclosed or suggested by Terry.

Watanabe (JP 2-117088 and JP 2-117089) teaches a method of capturing parasitic harmonics from the supply current for purposes of induction heating. Watanabe removes the undesired harmonic byproduct created when an AC voltage is rectified to a DC voltage and then filtered with a smoothing capacitor. The supply current is passed through several resonant circuits such that each of a plurality of heater coils receives a substantially pure sinusoidal signal (of a different resonant frequency). Thus, Watanabe provides a plurality of separately tuned resonant circuits delivering to each heater coil a substantially pure sine wave signal.

Figure 4 of Watanabe does not show the signal delivered to the heater coil. Rather, Figure 4 shows the <u>supply current</u> at an extreme distortion:

> "Consequently, the line currents of the various lines of 3-phase AC power source (A) usually become the distorted waveforms shown in Figure 4. Such waveforms differ from the sinusoidal wave, and they have plural harmonics superimposed on a fundamental sinusoidal wave (such as 50Hz, 60Hz)." (Watanabe at page 2, lines 17-20 of the English translation).

Thus, Watanabe does not teach or suggest creating Applicant's claimed apparatus and method for delivering to a heater coil non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics in the heater coil. Watanabe simply tries to find a use for an undesired harmonics component, and does so by creating multiple resonant sinusoidal signals in a plurality of different coils.

Pilavdzic (U.S. 2003/0121908 A1) describes a combination resistive and inductive heating system including a core and a yoke, wherein the heater coil is positioned in a groove provided between the yoke and core and the coil is in thermal communication with the yoke and core. However, there is no disclosure of using non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics in the heater coil, as claimed by applicant. Thus, the combination of Pilavdzic with either Terry or Watanabe would not produce the claimed signal. Nor is there any suggestion of how to combine Pilavdzic's combination (resistive and

inductive) heating system, with Terry's or Watanabe's quite different implementations utilizing some form of harmonics.

Nishi (U.S. 5,294,769) is cited by the Examiner as teaching a heating system which utilizes both resistive and inductive heating, although admittedly with no teaching regarding the use of harmonics. Nishi focuses on the temperature profile of the article being heated for the purpose of reducing thermal stresses while joining an electroconductive ceramic to a metal. Nishi teaches the use of two heating means, one of which may be inductive. The portion of Nishi relied upon by the Examiner, namely, column 13, lines 8-14, states that in "regard to controlling the ratio of resistance heating and inductive heating, resistance heating is more efficient (cost effective)". In regard to inductive heating, Nishi appears to teach the traditional "high frequency inductive heating equipment" (column 12, line 10). Thus, not only is there no disclosure of using applicant's claimed non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics in the heater coil, there is also no apparent reason for combining Nishi's resistive and inductive heating system with Terry's and/or Watanabe's quite different implementations utilizing some form of harmonics.

<u>Other Known Power Sources for Inductive Heaters</u>

A current injection type inverter has also been used for inductive heating. In this system, a capacitor is highly charged and then drained through a switch in series with the load and capacitor. A simplified inverter may have certain advantages like simplicity and low cost. Comiantel of Quebec, Canada sells a power supply for induction heating of calendar rolls that utilizes a current injection type inverter (see "Operator's manual"

and "Control Card Programmer's manual" submitted with the attached IDS). Moulinex of France also sells a power supply of this type for inductive residential cooking appliances (see, e.g., Malnoe US Patent 5,854,473 listed in attached IDS). However, while such power supplies deliver current pulses to the load, these systems do not deliver non-sinusoidal current pulses having steeply varying portions providing high frequency harmonics in the heater coil. In fact, the signal delivered to the load by these prior art power supplies is of substantially a single frequency. This signal may be slightly damped resulting in a small amount of harmonics. However, in no way could the pulses be considered to have steeply varying portions. Thus, to applicant's knowledge, such current injection type inverters have only been used to deliver pulses that are substantially sinusoidal. In contrast, Applicant's claimed non-sinusoidal current pulses having steeply varying portions which inevitably deliver to the article a substantial amount of pulse energy in the high frequency harmonics.

Summary of the prior art

The history of the known prior art in this field can be summarized as follows.

Traditional inductive heating systems utilize a resonant frequency power supply which delivers a sinusoidal current of resonant frequency to the heater coil. In such systems, in order to increase the heating power delivered to the load, a large current must be delivered to the load. There are numerous problems generated by the use of such large currents, including large power losses in the switching circuit, parasitic heating of the coil, the necessity for large tank capacitors (for tuning the resonant circuit), and the complexity of the switching circuit. Most notably, such systems deliver

to the load a sinusoidal resonant frequency current which signal is a continuous function of time.

It was postulated by Terry in GB 752,268 that a sinusoidal current comprising harmonics could produce high temperatures. Mackenzie US 4,085,300 and Hocking US 5,183,985 (D2 and D3 in the International Search Report, submitted in prior IDS) disclose similar subject matter. However, it has been found by practitioners in the field that the harmonics are difficult to control in a continuous signal and cause heating coils to burn-out. Accordingly, arrangements have been developed to specifically remove any harmonic components from the supply current prior to the current being provided to the heater coils. Such an arrangement is described in Sprenger US 5,847,370 (D1 in the International Search Report previously submitted) which utilizes a tank circuit to remove the harmonics. Another such arrangement is described by Watanabe (JP 2-117088 and JP 2-117089) in which the harmonic components are removed from the supply current and a plurality of separately tuned resonant circuits deliver to each of a plurality of heater coils a substantially pure sine wave signal.

Supplying substantially sinusoidal current <u>pulses</u> to a heater coil is also known. However, it has been naturally assumed by practitioners in the field that these pulsed current signals would suffer the same problems as with a continuous signal if harmonics were to be introduced.

In contrast to this general consensus in the field, the present Applicant has surprisingly found that by supplying <u>non-sinusoidal</u> current <u>pulses</u> to the heater coil having <u>steeply varying portions providing high frequency harmonics</u> in the heater coil then the lifetime of the heater coil can actually be enhanced and more rapid heating of

the article can be achieved. Furthermore, the harmonic content of the pulses can be varied leading to a very flexible and adjustable energy content delivery system for inductive heating. The presently claimed arrangement and its beneficial technical effects are neither disclosed nor suggested in the prior art. As such, the presently proposed claims are clearly inventive having regard to the state of the art.

Reconsideration

It is believed that all claims in the present application are now in condition for allowance.

Applicant will submit a terminal disclaimer if necessary.

Reconsideration of this application is respectfully requested. Because this application has been granted "Special Status", it is requested that such reconsideration be expedited. If the Examiner believes that a telephone conference would further prosecution of the present application, the Examiner is invited to call the applicant's undersigned attorney at the Examiner's earliest convenience.

Any amendments, cancellations or submissions with respect to claims is made without prejudice, and is not an admission that said cancelled, amended, or otherwise effected subject matter is not patentable or supported. Applicant reserves the right to pursue cancelled or amended subject matter in one or more continuation, divisional, or continuation-in-part applications.

Please grant any extensions of time required to enter this response and charge any fees in addition to fees submitted herewith that may be required to enter/allow this

response and any accompanying papers to our deposit account 02-3038 and credit any overpayments thereto.

Respectfully submitted

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